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ABSTRACT

The Zimbabwe Secondary School Science Project (ZIM-SCI) developed student study guides, corresponding teaching guides, and science kits for a low-cost science course which could be taught during the first 2 years of secondary school without the aid of qualified teachers and conventional laboratories. This ZIM-SCI study guide is a four-part unit consisting of activities and experiments in which students investigate: (1) the three states of matter (solids, liquids, and gases) and kinetic theory; (2) expansion and diffusion; (3) the behavior of gases; and (4) chemical reactions. Information to help students understand the scientific principles behind the activities and experiments is included throughout the unit. (JN)

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ZIMBABWE SECONDARY SCHOOL SCIENCE PROJECT

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STUDY GUIDE C2

Particles in Action

UNIVERSITY OF ZIMBABWE 2
AND MINISTRY OF EDUCATION AND CULTURE

SE 043 836

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JULY, 1981

Zim - Sci

Zimbabwe Secondary School Science Project

GENERAL SCIENCE

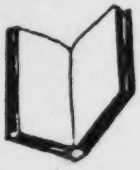
STUDENTS : Please read this carefully. It will help you.

How you will study

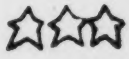
This study guide comes to you with a kit of apparatus. Both things are part of a study programme leading you to an understanding of aspects of science. In this course you will be carrying out experiments. The study guide will help you to understand the scientific principles behind the experiments.

Your work should be done as you are instructed, either by the teacher or the study guide.

To help you to see quickly what you must do, the study guide uses these symbols.



for "Read and revise your notes and Study Guide"



for "Take note of an important point that you should learn."

for "Summary". This is to help you to go over what you have learned.

GENERAL SCIENCE

UNIT C2 : PARTICLES IN ACTION

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AIMS OF UNIT C2

When you have completed this study unit you will be able to:

1. State the three states of matter.

2. Describe matter in terms of very small particles which are moving all the time.

3. Describe temperature in terms of particle motion.

4. Make a model of the structure of matter.

5. Explain expansion, diffusion and changes in density.

6. Explain the connection between pressure and volume in a gas.

7. Define the molecule.

GENERAL SCIENCE UNIT C2

PARTICLES IN ACTION

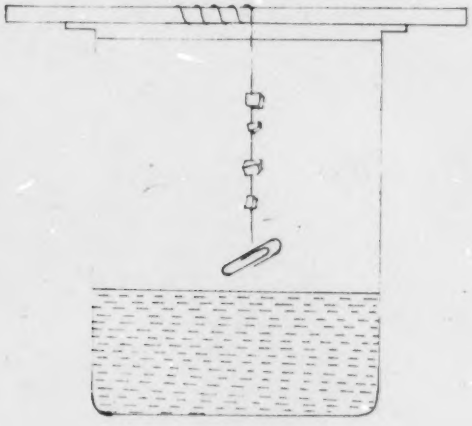
PART 1

THE THREE STATES OF MATTER

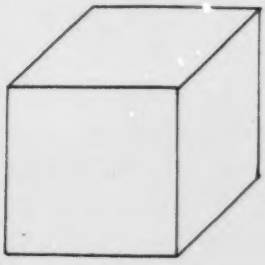
In the last unit, you learned something about the way particles behave, particularly when they are reacting. You also learned the important part energy plays in chemical reactions.

At the end of Unit C1, you began an experiment to join up particles of sodium chloride into crystals by growing them on a string.

First of all, let us take a look once more at your crystals. Use your handlens to study them closely.



Did you find some good crystals on your string? Perhaps you found just a few on the string, and many more on the top of the sodium chloride in the cup. What shape are the crystals? Do you know the name we give to this shape? We call it cubic.



a cube

A cube has all its sides of equal length. Probably you have learned this before, in your Maths lessons. Not all crystals have cubic shapes - we shall now have a look at a different sort of crystal and see what shape we get.

Find the little piece of naphthalene in foil that you MELTED in Unit A1. You should have it in your basic kit box. Can you find it? It probably looks dirty and lumpy now - it might even be a pale orange colour. You are now going to break up this lump and then allow the particles to come together freely just as you did for sodium chloride. In this case, however, you can do it more quickly; you don't have to take a whole week!

EXPERIMENT 1 To make Crystals of Naphthalene

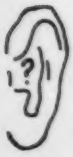
You will need:

- your burner and stand
- your evaporating tin
- your boiling tin, almost full of cold water
- your peg
- your foil container of naphthalene

Set up your burner and stand. Take the naphthalene out of the foil container and put the lump of naphthalene on the evaporating dish. Now heat the dish gently. You will see the naphthalene melting in the dish. Hold the boiling tin half full of cold water above the evaporating dish as shown in the diagram and continue heating until all the naphthalene has gone away. BE CAREFUL in this experiment. You might set the naphthalene on fire and then it will be wasted. DO NOT heat too much! If it should catch fire, blow it out quickly.

Boiling tin with cold water held right over the top of the evaporating dish of naphthalene.

When all the naphthalene has gone away, blow out your burner straight away. Remove the boiling tin and look underneath. What do you find? As soon as your evaporating dish is cold, scrape the crystals back off the boiling tin into the COLD evaporating dish.



Have a look at the crystals now. What colour are they? If the naphthalene is now a different colour, what does this mean? Discuss this with your teacher.

What shape are these crystals? They are FLAKES - flat on the top and bottom, thin, and of varying size. So you can see that crystals can take different forms. Some are cubic, like your sodium chloride, some are flakes, like your naphthalene, some may be needle-shaped, some eight-sided, and so on. The important thing to note is that each crystal of a substance is the same shape as other crystals of the same substance. The crystal shape is REGULAR - that is to say, it grows in a uniform way, and we can be sure that ALL crystals of naphthalene will be flakes. This is very important, because it tells us quite a lot about SOLIDS.

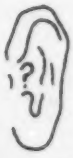
Now answer Exercise 1.

Clean your boiling tin by rubbing the surface with a piece of newspaper. Wash the tin and half fill with water. While it is still wet, place it on the burner stand and heat. The flame will remove any naphthalene remaining on the outside.

From primary school, you already know that there are three states of matter - SOLID, LIQUID and GASEOUS states. In this unit we shall try to find out more about these states, and about how the particles behave in each of them. The whole subject of states of matter is called KINETIC THEORY. 'Kinetic' means 'moving', as you learnt in your energy unit (Unit B). Why should the states of matter be moving? Let us look at each of the three states in turn, and perhaps we shall find out the reason.

We have already discovered that particles, coming together to make solid shapes, do so in a REGULAR way. They also get as close together as they can. We mentioned in the last unit that this is called CLOSE PACKING. So we can be sure that all solid substances have particles which are close to each other, making a regular shape.

Look around you. You will see many, many solid things held together by closely packed particles. It is a very good thing that they can get so close together because they then make shapes that we want, shapes that we can use. You will have a pen or pencil in front of you. Feel it with your fingers. It feels hard doesn't it? That is because the particles of the pen are all very close together and squashed up in a small space. They can't move around very much, so they feel firm when you push on them. Do you think that the particles of a solid have any movement at all? Listen to your teacher now.



We call this kind of side to side movement VIBRATION - particles of a solid can vibrate in all directions but they cannot move very far without banging into another particle. The particles are very small and so closely packed that we cannot see the sideways movement.

What about liquids? As you know, we can change a solid into a liquid by heating. You did this with naphthalene in Unit A1. You can observe closely now and try to guess what the particles are doing.

EXPERIMENT 2 Heating a solid

Take your flakes of naphthalene in the evaporating dish. Now heat very slowly over your burner as shown in the diagram and watch carefully as it melts. Do not heat too much - just enough to start it melting. Try to see what is happening to the solid naphthalene as you heat it.

Heat for just a short time, then blow out burner flame.

Did you watch carefully? Then you will have noticed that when the naphthalene melted and became liquid naphthalene, the flakes all broke up. You were left with one big drop of liquid naphthalene in the dish. Why did this happen? What has happened to the particles? Are they still in a regular shape, packed closely together? If they are not, what shape are they now?

Leave the naphthalene in the evaporating dish for the moment.

Now answer Exercise 2.

Your liquid particles move more freely. They are no longer as closely packed and they are further apart than in a solid.

So we believe that liquid particles probably have more energy than solid ones, because they are moving about more freely. Heat energy gives them the ability to move. If this is true, then particles should lose heat energy when they move closer together. They should give out this heat energy while changing from a liquid to a solid.

We shall perform another experiment now on a different substance to see whether particles do give out heat energy when they form a solid. We shall be able to watch the crystals growing slowly, as the solid pieces get bigger and bigger.

EXPERIMENT 3 To observe what happens when Crystals of Sodium Thiosulphate are made

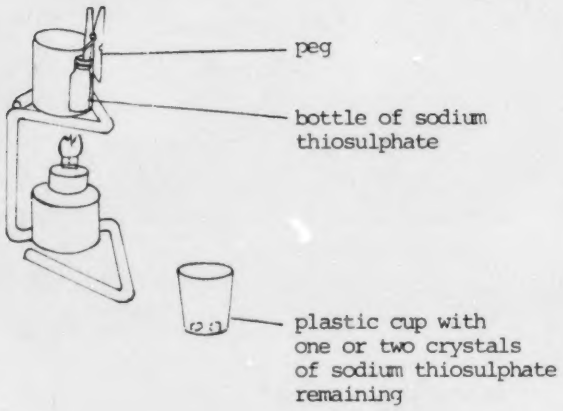
You will need:

your boiling tin half full of water)
your burner)
your burner stand) from
your peg) your
a small plastic bottle) basic
your plastic cup) kit
4 spatulas sodium thiosulphate (from your teacher)
a handlens (from your teacher)

Put the tin of water on the burner stand to boil. Spread out the sodium thiosulphate in the plastic cup and have a close look at it.

It consists of many small crystals, doesn't it? Choose one or two crystals (if you can see any big ones, choose those) and keep them in the plastic cup. Put all the rest of the sodium thiosulphate into the plastic bottle. When the water is boiling, hold the bottle in the water with the peg until the sodium thiosulphate melts to form a liquid.

This is shown in the diagram.



As soon as it has all melted, take the bottle out of the water and allow it to cool down completely. This will take some time. While you are waiting, write a report of what you have done so far in your book (Exercise 3). Remember to write:

what you were trying to find out;
what you did (including a diagram of your apparatus)

As soon as your bottle is quite cold, you are ready to continue. DO NOT go on with the experiment unless the bottle is completely cold! You will see that your bottle does NOT contain a solid yet. Although it is cold, no crystals have grown in the bottle. Why not? Well, these crystals are like the salt crystals you made before - they need something to fasten on to. That is why you have kept back one or two crystals in your plastic cup. As soon as your liquid is cold you can drop these crystals into the liquid in the bottle, so that bigger ones can start to grow.

Drop them in, and then OBSERVE VERY CAREFULLY WITH YOUR HANDLENS. You will see big crystals growing. When they are nice and big, feel the outside of the bottle. What do you find?

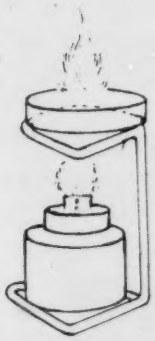
Finish your report now, and then answer Exercise 4.

Do you remember your experiment on heating naphthalene in Unit A1? You saw that the temperature stayed the same (about 78°C) for quite some time. This is because the liquid was changing to a solid and GIVING OUT HEAT as it did so.

All this seems to support our idea that particles which receive extra energy move around more freely. If the energy is removed, they are able to come closer together and form a solid. What happens if the particles of a liquid are heated up even more?

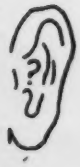
EXPERIMENT 4 Heating a Liquid

Go back to the naphthalene in the evaporating dish and heat it again. Remember to heat carefully. First it will become liquid. After that, as you go on heating, you will see white smoke coming off. As soon as you have seen the white smoke, BLOW OUT YOUR BURNER, REMEMBER THE NAPHTHALENE MIGHT CATCH FIRE!



What are these white fumes?

Did you guess that they are particles of naphthalene leaving the liquid and going into the air? The naphthalene has become a GAS. From your knowledge of particle movement so far, what could you guess about the movement of gaseous particles? Are they free, or not? Are they as free as in a liquid, or more so? What do you think? Tell your teacher.



If we cool down a gas, it should become a liquid. Let us try this now.

EXPERIMENT 5 Cooling Steam

Throw away the naphthalene and clean the evaporating dish well with newspaper and warm water as you did for your boiling tin in Experiment 1. Now put some clean water into the clean evaporating dish and heat to boiling.

Hold your hand above the boiling water in the gaseous steam - not too close!

Take your hand away - what do you see on your hand?

So the gaseous STEAM turned back to liquid WATER on your cool hand. You cooled the gas and took away some of the energy of the particles. Some of the heat energy left the particles and went somewhere else. Where did this heat energy go? Something must have got hotter - what was that?

Now answer Exercise 5.

Next you will observe a piece of wax, changing from one state to another as you heat it.

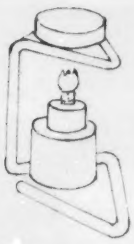
EXPERIMENT 6 Heating Wax

Your teacher will give you some wax. Place it in the evaporating dish and heat gently until it melts. Watch carefully as it changes from solid to liquid. You will have to answer some questions about your observations soon.

Once it has melted, keep heating it. You will see that the liquid wax is getting less and less. Where is it going? Into the air, as gaseous wax particles! When wax gets hot it will burn, so you can show that there are gaseous particles above the dish, by setting fire to them.

Please turn over

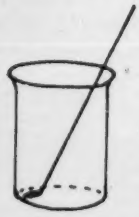
Take a match and light it. Hold it ABOVE the dish, in the region where you think the gas may be. Did it catch alight? The flames probably jumped downwards into the dish and all the wax probably burned away. That is quite all right!



You use wax often as a source of light and heat, in a CANDLE. Your teacher will give you a CANDLE now. Set it firmly in the evaporating dish. If there is some wax left in the dish it doesn't matter. A burning candle is an excellent way to show all three states of matter at once. Before you begin, try to think of which substance in a candle burns to give light. Is it the wax, or is it just the wick (the cotton stuff in the middle)? To help you to get the answer, try to think of what it is that gets finished up when a candle burns. Does the wax get shorter? If so, the wax must be burning.

EXPERIMENT 7 To observe a Burning Candle

Light your candle now and observe the wax around the flame. Is it changing state? Which states are involved here? Now you can try to find some gaseous wax particles. You cannot see them, so you will have to try to burn them. Study the diagram before you try the experiment and read the rest of the instructions carefully!



Light another match.

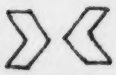
Cup your hand around the flame. Quickly blow out the candle flame and then put the lighted match just above the wick, but not touching it. What happens?

Now answer Exercise 6.

So a burning candle has solid, liquid and gaseous particles, all present at the same time. We are now in a position to make a table about the three states of matter, to summarise all we have decided so far. When we form an idea by observation and by some good guesses, we call the idea a 'DEDUCTION'.

KINETIC THEORY OF MATTER

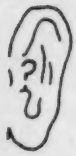
Here are our DEDUCTIONS about the three states of matter.



SOLID	LIQUID	GAS
Particles are very close together	Particles are further apart and have more energy than solid particles	Particles are very far apart and have more energy than liquid particles
Energy taken in →	More energy taken in →	
	← More energy given out	← Energy given out
Particles can shake in vibrational movement but cannot move very far because they are closely packed	Particles can travel around in the space occupied by the liquid but are not completely free	Particles are completely free to move around a very big space

14

Now your teacher is going to tell you about a MODEL of particle movement. Listen carefully.



So you have learned quite a lot about the three states of matter. Well done!

Before you go on to the next section of the Unit, you should prepare an experiment for later on.

You will need:

- 2 bottles
- boiling tin
- burner and stand
- stirrer
- 5 ml measure
- gelatin
- water

) from your basic kit

Half fill your boiling tin with water and put it on to boil. While it is boiling, put 2 spatulas of gelatin into each bottle. Add 10ml cold water to each bottle and stir well.

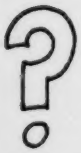
When the water is boiling, add 10ml boiling water to each bottle. Stir until all the gelatin has dissolved. Leave to set into a solid jelly-like form. This may take some time, perhaps a whole day!

Put the caps on your bottles and keep them in a safe place (standing up) until you need them for Experiment 10.

You should now spend a whole lesson revising Part 1 of this unit. Read it often so that you can be sure you understand it well.

HOW MUCH DO YOU KNOW?

Answer the following questions in your exercise books.



1. There are three states of matter. They are called the ....., ... and ..... states.
2. When a solid is heated it becomes a .....
3. When a liquid is heated it becomes a .....
4. If a gas is cooled down it turns into a ..... and gives out ..... as it changes from one state to the other.
5. If a liquid is cooled down it ....
6. The state in which particles are very far apart is the ..... state.
7. The state in which particles are closest together is the ..... state.

PART 2

EXPANSION AND DIFFUSION

Now that your model has given you some understanding of the three states of matter, you can try to find out more about them.

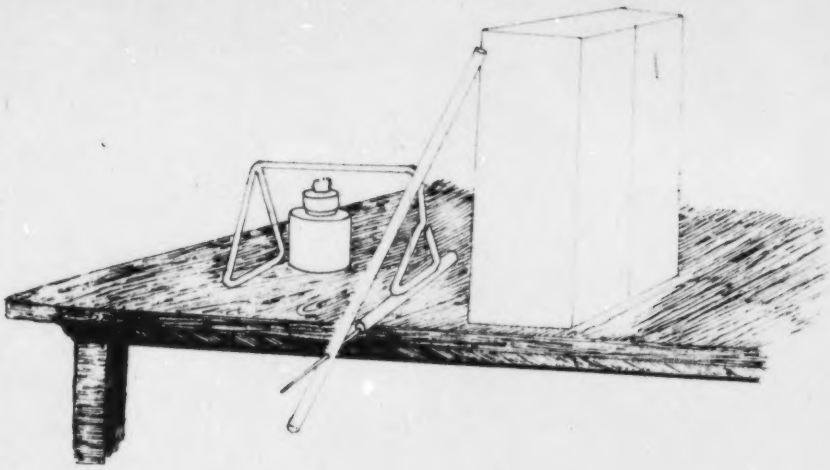
You have discovered that solids change into liquids when they are heated. What happens to the particles before they reach the melting point? You decided that they could vibrate from side to side, and that they would have more movement when they were heated. Think about the model you made. Do you remember that you could move from side to side more and more as you 'vibrated'? You moved further away from your neighbours as you used more energy. So we think that particles of a solid might move apart when they get more energy. If this is true, the solid must get BIGGER because the particles are further apart than they were before. You observed this with your model. Can we show this by experiment?

EXPERIMENT 8 What happens when a Solid is Heated

You will need:

- burner and stand
- straw
- mounted needle
- basic kit box

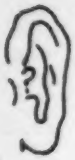
First push the needle through the straw at a point 4cm . from one end.



Then set up the apparatus as shown in the diagram. The basic kit box should be placed JUST behind the 'pointer' made by the end of the straw. Do not light your burner yet. If the metal stand gets bigger, it will move the wooden rod at the bottom of the mounted needle. Then the pointer will move. Try moving the burner stand by hand slowly to the right and left. What happens? Set up the apparatus again. Now you are ready to begin. Light your burner and heat the bar in the middle as shown. Watch the pointer. What happens now? When you have seen the result of heating, blow out the burner. Watch the pointer as the bar cools down again.

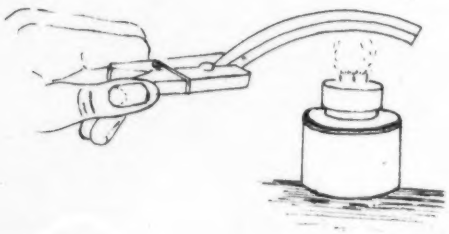
When solids get bigger on heating, we say they are EXPANDING. They get bigger in ALL DIRECTIONS.

So a solid does get bigger (EXPANDS) when it is heated. Do all solid substances expand by the same amount? Perhaps particles of one kind of substance move further apart than others of a different kind?



Listen to your teacher again now as he shows you another experiment on solid expansion.

EXPERIMENT 9 The Bimetallic Strip



You now know that different solids expand by different amounts. Scientists have found that particles of one kind may be held to each other more tightly than particles of another kind, so that they are less free to move. This means that for the same heat energy added, different substances will expand by different amounts.

Even though the solid particles are close together, because they are vibrating there must be spaces between them. You made spaces between you and your neighbours when your model vibrated. Can we show by an experiment that the spaces are there in real matter? The next experiment aims to demonstrate this interesting fact for a solid. You are going to write a report on this. Write the AIM of the experiment in your exercise book before you begin the report. Then write down what you did. Lastly record your observations and what these observations told you.

EXPERIMENT 10 Are there Spaces between the Particles of a Solid?

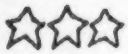
Find the bottles of solid gelatin that you made earlier. It should be really solid now and should not fall out if you turn the bottles upside down.

Your teacher will give you some copper sulphate and some ammonium dichromate.

Place just a few crystals of ammonium dichromate on the top of the solid gelatin in the first bottle. Repeat for copper sulphate in the second bottle.

You will be able to get an idea of what is happening after a few hours, but it would be better to observe over a few days.

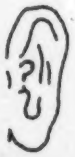
Complete Exercise 7.



When one substance spreads through another substance, as your crystals spread through the gelatin, the process is called DIFFUSION. We say that the particles of copper sulphate DIFFUSED through the gelatin. They can only do this if there are spaces between the gelatin particles. The copper sulphate or ammonium dichromate particles can move into these spaces.

If there are small spaces between particles the solid will be very closely packed. We say that it is 'DENSE'. The gelatin you used in Experiment 10 was not very dense. The spaces between gelatin particles were quite large.

Could you speed up this DIFFUSION? There are two ways you might do this. Firstly, you could make the gelatin particles move about more quickly, so that the spaces are bigger. Secondly, you could make the copper sulphate pieces smaller so that the particles could move more quickly into the gelatin.

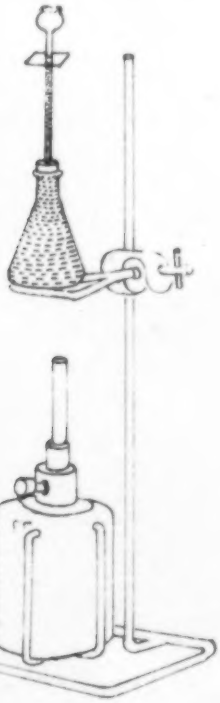


Discuss this with your teacher. You might even have time to try out your ideas in practice.

Now we shall have a closer look at LIQUIDS. You have already seen that liquid particles move about more freely than solid particles. They are not packed together so closely and tightly: they are LESS DENSE than solids.

What will happen to the spaces between the particles in a liquid when you heat it? Listen to your teacher.

EXPERIMENT 11 Does a Liquid expand when it is Heated?



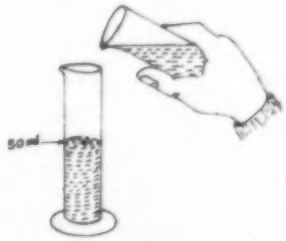
Experiment 11 shows that liquid particles move further apart when heated, just as solid ones do.

Your gelatin diffusion experiment showed that there are spaces between the particles of a solid. If your idea of a liquid is correct, then the spaces in a liquid should be bigger than those in a solid because the particles are further apart.

EXPERIMENT 12 To show that there are Spaces in a Liquid

Listen to your teacher as he shows you what to do.

Then answer Exercise 8.



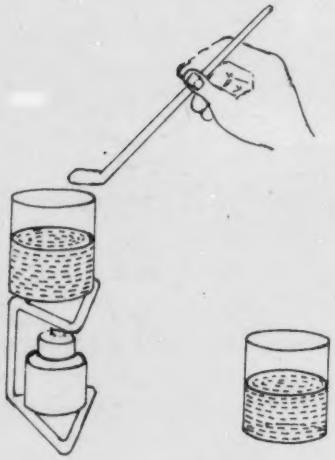
You will remember that in Unit C1, you observed a piece of copper sulphate slowly dissolving in water. The blue colour slowly diffused through the water. You can now make some guesses about the way in which this happened. After the water pulled off the copper sulphate particles, how did they spread through the water? Discuss this with your teacher.

If you assume that the particles are all moving about, then you should find that diffusion in liquids happens more quickly if the liquid is hot. This is because we believe that hot particles have more kinetic (motion) energy than cold ones. Can you show by experiment that diffusion happens more quickly in a hot liquid?

EXPERIMENT 13 Does diffusion happen more quickly in a Hot Liquid than in a Cold One?

You will need:

your boiling tin
your plastic cup
some water
some copper sulphate (from your teacher)
your burner and stand



Fill both the plastic cup and the boiling tin half full of water. Put the boiling tin on to boil.

Put half a spatula of copper sulphate into the water in the PLASTIC CUP. DO NOT STIR! Watch it dissolving slowly. You will see the blue colour diffusing through the water as the particles spread out.

When the water in the boiling tin is boiling remove it from the flame and add half a spatula of copper sulphate to this hot water. What happens to the blue colour this time? What does this tell you?

Now answer Exercise 9.

Generally, liquids are less dense than solids because the particles are further apart. Gases must be even less dense, because their particles are moving about freely in a big space. Let us look at the effect of heating a gas and giving the particles even more energy. The easiest gas to choose for experiments is air.

EXPERIMENT 14 Heating a Gas

You will need:

- burner and stand
- boiling tin full of boiling water
- balloon
- strip of paper 1cm wide and about 50cm long (or 2 strips totalling this length)
- starch
- spatula
- evaporating dish
- bucket of water
- 5ml measure

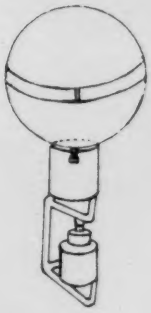
You will need some glue in this experiment. This is how to make it:

Put 2 spatulas starch into the evaporating dish. Add 10ml boiling water and stir to make thick glue. If there is not enough water, add some more.

Please turn over

Now blow up the balloon a little bit. You are putting air into it. Tie a knot in the balloon so that the blown up size is about the same size as a lab gas cylinder - about 10cm diameter. The size is NOT VERY IMPORTANT, just get it approximately correct. Cool the balloon in a bucket of water and dry it. Now, using your spatula, put small blobs of glue all around the widest part of the balloon and stick the paper strip on it so that the edges just meet as shown in the diagram.

Make sure that your water is boiling well and put the balloon on top of the tin. Watch carefully - what do you see?



You can do a second experiment on gaseous expansion now.

EXPERIMENT 15 Another look at a Gas expanding

You will need:

10ml syringe

the tin of boiling water from Experiment 14.

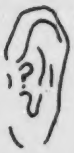
Have a look at your syringe. You will see that the plunger can be pushed in and pulled out freely. The measurement of the VOLUME of air is shown on the scale outside the syringe. Set the syringe at 10ml. Then it contains 10ml AIR.

Put the syringe into the very hot water as shown in the diagram. Watch the open end of the syringe (the end under the water) closely. What do you see?

Now answer Exercise 10.

Lastly, let us look at diffusion in a gas.

If the particles of a gas are moving more freely and have more energy than those of a liquid, then the process of diffusion should be very fast. Iodine is a solid which changes easily into a gas. The gas is easy to see because it is a purple colour. The purple iodine particles can be OBSERVED diffusing through the air.



Your teacher will show you this now.

EXPERIMENT 16 To observe Gaseous Diffusion

Now we shall use another of our senses - our sense of smell - to observe gaseous diffusion. If we can smell gases, we must be taking gas particles into our nose. They must be present in the air we breathe, or we would not be able to smell them. You can get an idea of the speed of diffusion of ammonia particles in the following experiment.

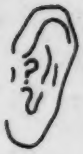
EXPERIMENT 17. To find out how fast Ammonia Particles diffuse in air

Your teacher will drop some strong ammonia solution into an evaporating dish in the middle of the classroom. You should watch the clock. When the teacher says 'Go', and puts the ammonia into the dish, you should time how long it takes for you yourself to smell the ammonia. Of course if you are at the back of the class it will take longer.

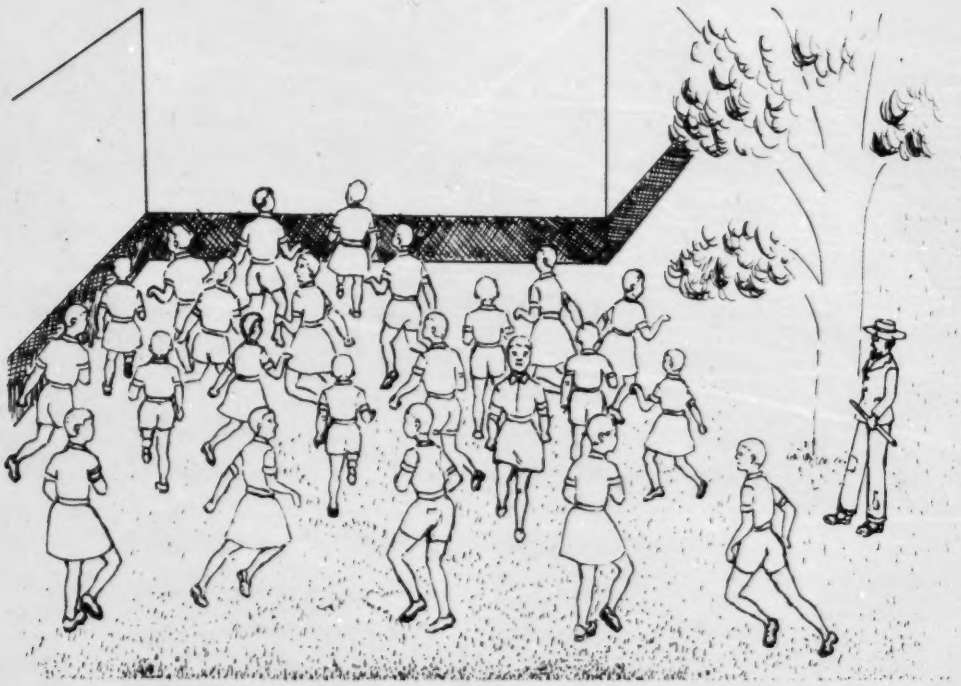
Record how long it takes for you to smell the ammonia. Measure the distance between you and the evaporating dish with a metre rule.

Record your results in Exercise 11 and work out the speed of the ammonia particles. Compare the results around the class. Do you all agree?

An interesting point to note here is that there is very little ammonia in the dish, yet the particles are spreading out into the big classroom full of air. There must be many ammonia particles coming into the air or you would not be able to smell them. This is, therefore, another experiment which shows how SMALL the particles must be.



We will now make a model again. Listen to your teacher now.

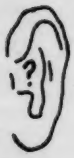


TO SUMMARISE: the model shows us that:

1. Gaseous particles diffuse into each other rapidly.
2. When the volume of a gas becomes smaller the particles move closer together and bump into the walls of the container more often..

The last experiment in this part of the unit is a very important and famous one.

Suppose you put some very very small pieces of a solid into a liquid like water. The pieces are so small they can only just be seen. You know that the invisible particles of the water are moving around (just like you did in the model). What would you expect to see happening to the small pieces of solid?

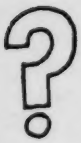


EXPERIMENT 18 Seeing the effect of Particle Movement in Water

Listen to your teacher now.

Take time now to revise Part 2 of this Unit. Spend a whole lesson on revision. Then answer the following questions in your exercise book.

HOW MUCH DO YOU KNOW?



1. When substances are heated, they .....
2. Movement of particles of one substance through another substance is called .....
3. This process is fastest in .....
   slower in .....
   slowest in .....

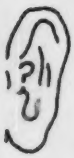
PART 3

GASEOUS BEHAVIOUR

In this section of the Unit, you are going to take a closer look at gases and how they behave. We shall be using air as an example of a gas. Earlier in the unit, you learned that gases are made up of particles moving fast and freely through a big space. They bang into each other sometimes, and they bang against the walls of a container. In fact they bang against anything which gets in their way! Particles of air are bumping against you all the time!

You are used to this bumping so you don't notice it. This bumping or pressing of gas particles is called PRESSURE.

From your model you made earlier (when you yourself pretended to be a gaseous particle) you will remember that a gas can be squashed up quite a lot. The space it occupies (the VOLUME) will get smaller, and the bumping against the walls (PRESSURE) will get bigger. When the gas particles are in a small space, they will bump against the walls of the container more often than in a big space. We say that the 'pressure is greater' because the banging force on the walls gets bigger.



We can show this using a bicycle pump. Your teacher will show you one now, although you are probably very experienced in using such a pump!

Now let us imagine that it is possible to take away some of the particles of air in a container. Then the pressure would be very small because there would be very few particles bumping against the walls. You can observe this effect now with the syringe experiment that you set up before.

EXPERIMENT 19 What happens when some of a gas is taken away?

Read all the instructions carefully before you begin.

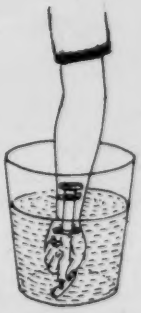
You will need:

- 10ml syringe
- boiling tin
- burner and stand
- water
- bucket of cold water

Set up your burner and stand and heat your boiling tin full of water. While you are waiting for the water to boil put your finger over the small open end of the syringe and try to push in the plunger. You will feel the pressure of the air inside the syringe getting bigger as you try to squash it into a smaller volume.

Set the syringe so that the volume inside is 10ml. The syringe now contains 10ml AIR. When the water is boiling, place the syringe in the water as shown in the diagram and hold it there for half a minute to allow the air to expand and bubbles of it to escape.

Quickly pull the syringe out of the water and place your finger firmly over the small open end. Keeping your finger on the end, place the syringe in the cold water in the bucket as shown. Leave the plunger free to move. Keep the syringe in the bucket for about half a minute. Do not put all the syringe under the water. Once the plunger has moved, you can take the syringe out of the water and take your finger off the end.



Now answer Exercise 12.

So the plunger had to move inwards because there were fewer air particles inside the syringe than there were when you started the experiment. Study the diagrams below so that you understand this idea fully.

AT THE START

many particles banging against the plunger

many particles banging against the plunger

The plunger does not move because there are many air particles on both sides banging against it. The PRESSURE is equal on both sides.

After heating and bubbling there are fewer particles on the inside BUT they are moving faster because they are hot and can give the same pressure as before.

AFTER COOLING

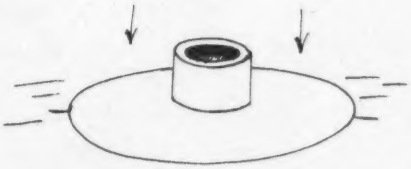
many particles banging against the plunger

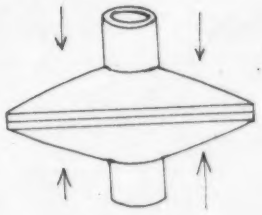
fewer particles banging against the plunger

After cooling all the particles on both sides of the plunger have the same energy. There are more particles on the outside of the plunger than on the inside so the banging pressure is greater on the outside and pushes the plunger inwards. It stops moving inwards when the pressure is once again the same on both sides of the plunger. This happens when the volume is just right for the few particles left inside the syringe to make the same number of bumps against the plunger as those outside.

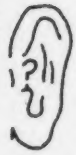
You will remember from your model that when you pretended that the walls 'moved inwards' towards you, you had less room to move. You banged into each other and into the walls of the container more often. In the same way the particles inside the syringe are now banging against the plunger more often than they were before. The pressure becomes equal on both sides again.

Now your teacher has some rubber suckers to show you. He will make them stick to different surfaces in the classroom, and perhaps pass them round for you to see. How do they work? Answer Exercise 13 now.





After you have all looked at a rubber sucker, your teacher will stick two together and pass them round again. Try to pull them apart this time. Why is it even more difficult than it was before? Discuss this with your teacher.



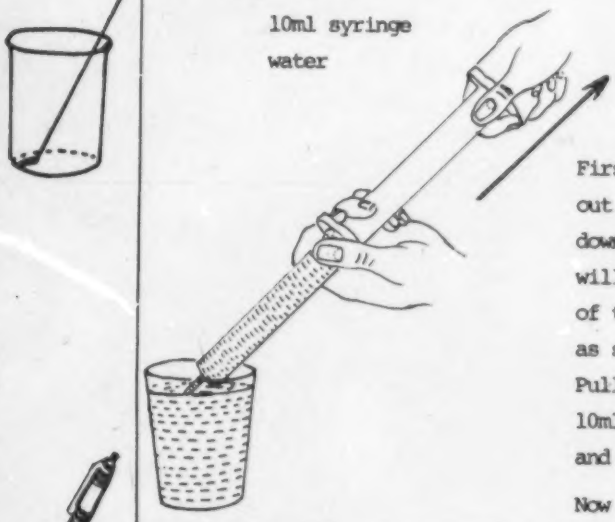
The next experiment is another syringe demonstration. Try to explain exactly what is happening in KINETIC terms - that is, in terms of particle behaviour.

EXPERIMENT 20 The proper use of a Syringe

The syringe was designed to be used by doctors to inject medicine into animals and humans. In this experiment you will find out how it works.

You will need:

10ml syringe
water



First, push all the air out of the syringe by pressing down the plunger as far as it will go. Then put the end of the syringe under the water as shown in the diagram. Pull the plunger out to the 10ml mark. What happens, and why?

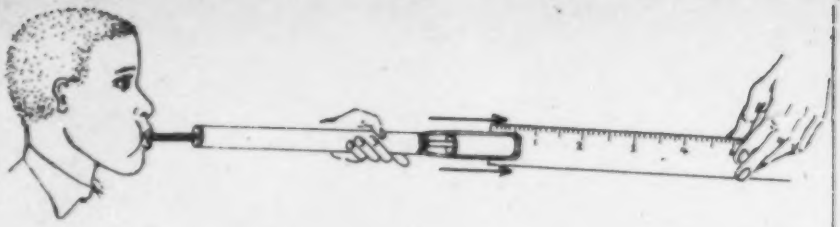
Now answer Exercise 14.

MEASUREMENT OF PRESSURE

In Unit A1 you learned about the importance of measurement to the scientist. Here is one way in which you can measure pressure.

EXPERIMENT 21 To compare pressures of Pupils' Lungs using a Pressure GAUGE

Your teacher will set up and explain the apparatus shown in the diagram.



If you blow down the tube, you are pushing air particles from your lungs into the tube. The pressure then becomes greater on that side than on the other, because there are more particles on that side than the other. What will happen? Try it and see!

Now answer Exercise 15.

You have learned a lot more about particle behaviour now. Whenever you are thinking about the behaviour of matter, try to imagine it in simple kinetic terms. It will make the understanding of it much easier!

Spend a whole lesson revising Part 3 of this Unit. Then answer the following questions in your exercise books.

HOW MUCH DO YOU KNOW?

1. Bumping of air particles against the walls of their container is called .....

2. If the volume gets smaller, the pressure gets .....

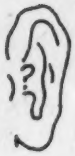
3. If some gas particles are taken away, the pressure gets (a) bigger; (b) smaller; because
   .....
   .....

4. If gas particles are heated without their being allowed to expand pressure gets bigger because
   .....
   .....

5. We can measure pressures with a .....
   .....

PART 4

CHEMICAL REACTIONS



You are going to make your particle model once more. Listen to your teacher now.

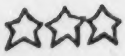
Your model showed that when chemical reactions happen, particles bump into each other and join up together. They need quite a lot of kinetic energy to do this.

We defined the 'smallest possible particle' as the ATOM in Unit C1. Can you remember the definition? To refresh your memory, here it is again:

> The atom is the smallest indivisible particle of an element which can take part in a chemical change.

When you were running about freely pretending to be particles reacting, you were really behaving like atoms. When you joined up to form a compound, you were making a new kind of particle. We call this 'joined-up' kind of particle a MOLECULE.

Definition:



> A molecule is the smallest part of a compound which can exist in a free and separate state.

Think back again to Unit C1 - to the iron sulphide experiment. In that experiment you began with two solids: iron and sulphur. You gave them some heat energy in order to set the reaction going. The particles got more and more energy. When the particles had enough energy to bump into each other and react, they formed a compound. They formed MOLECULES of iron sulphide.

We can write:

atoms of iron + atoms of sulphur ——→ molecules of iron sulphide

Any atoms left over (which could not find a partner) could not take part in the reaction.

You can do one more chemical experiment now, first to make a compound and then to break it. While you are doing the experiment try to think about the atoms bumping into each other to make molecules.

EXPERIMENT 22 To make and break a Compound

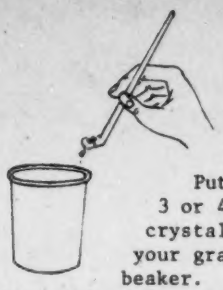
You will need:

- your graduated beaker
- your spatula/stirrer
- your burner and stand
- your evaporating dish
- your 5ml measure
- some water
- 3 or 4 iodine crystals
- some iron filings
- a magnet

The compound you will make in this experiment is IRON IODIDE. This is made by joining iron and iodine together. A small amount of heat energy is needed for this reaction to take place.
Now follow the flow chart.

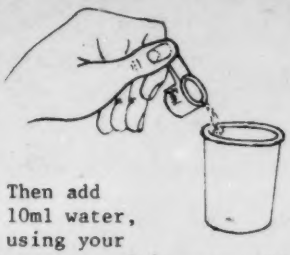
Please turn over

1



Put the 3 or 4 iodine crystals into your graduated beaker. Squash them with your spatula to make many small pieces.

2



Then add 10ml water, using your measure. Stir very well. Some of the iodine will dissolve, the water will become pale yellow in colour. Then add 1 small spatula full of iron filings. Stir very well again.

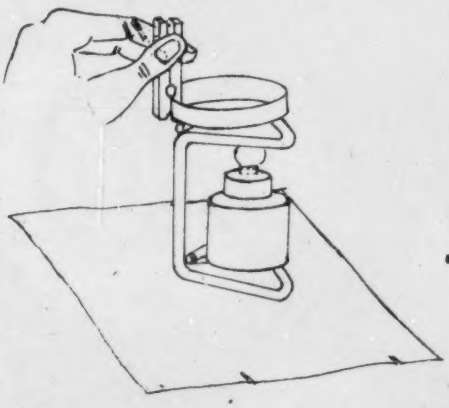
3

After some time, the water will become a red-brown colour. This means that more iodine is dissolving and reacting with the iron. When you have stirred well, pour the liquid part CAREFULLY into your evaporating dish.

4

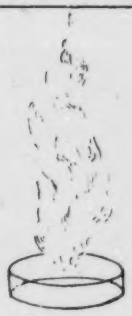
You can add 5ml water once more to the graduated beaker, swirl and add to the evaporating dish to be quite certain that you have got out all the reacting substances. Be VERY CAREFUL when you pour the solution into the dish.

5



Now heat the evaporating dish over the burner to drive off the water. Put the burner and stand on an old piece of paper while you are heating, as it might spit a little on to the desk. Once more you must be careful. Keep the dish quite flat on the stand using your peg to help you.

6

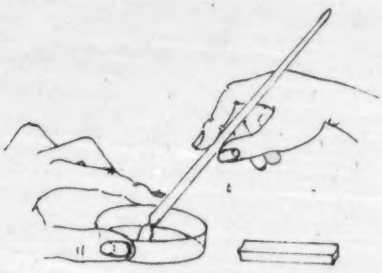


When it is almost completely dry, remove it quickly and let the last little bit of water evaporate without the heat. If you heat too much once it is dry, the experiment WILL NOT WORK!

7

While the water is evaporating, think about the following questions:

1. Why did you need water in this experiment?
2. What will be left when the water has all evaporated?
3. What are the atoms of iron and iodine doing while you are waiting?



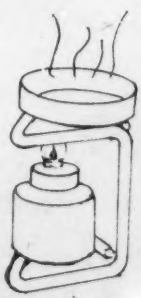
As soon as the water has evaporated, allow the dish to cool completely. Use your spatula to scrape a few pieces of the compound off the bottom of the dish. You will not have a lot of compound, but you should be able to scrape up a few small pieces. They will be grey in colour. Test them with a magnet. They should not be attracted to the magnet. If they are a little attracted, you probably have a few iron filings there by mistake.

So you have now made a compound:

atoms of iron + atoms of iodine ⟶ molecules of iron iodide

Think about the atoms of iron and iodine, all joined up to make molecules. To break up these molecules you will have to give them a lot of energy, so that they can vibrate until the atoms get free of each other once more. You will have to heat them. You will be able to <u>see</u> the iodine particles breaking free as 'iodine gas' because the colour of iodine in the gaseous state is <u>purple</u> (reddish-blue). (You have seen iodine gas before.) Iodine in the gaseous state is not very good for you to breathe into your lungs, so you should <u>finish off this experiment outside</u>.

8



Take the burner outside and heat the evaporating dish again. Watch the purple fumes coming off. When no more fumes come off bring back your tin and burner and have a look at what remains. What do you think it will be?

9

When it is cold scrape it up and test it with a magnet.

Then answer <u>Exercise 16</u>.

Now that you have finished the Unit, spend a lesson on revision of Part 3. Then read the summary that follows:

Afterwards you should re-read the whole unit, and see how we have built up our ideas. Using the evidence of our senses, we have started with a simple statement of the three states of matter and ended with a good idea of how particles behave. The evidence has been used, step by step, to develop the Kinetic Theory.

Here is a summary of all that we have DEDUCED in this Unit.

1. Kinetic Theory of Matter

Solid	Liquid	Gas
Has definite size and shape	Has definite size but no definite shape	Has no definite size and no definite shape
On heating: expands and then changes to a liquid	On heating: expands and then changes to a gas	On heating: expands very much
Diffuses slowly	Diffuses fairly fast	Diffuses very fast
Particles are close packed and can vibrate. Cannot move very far. Spaces between particles are very small	Particles are further apart than in a solid. They have more freedom of movement because they have more energy	Particles are very far apart. They are completely free to move. They have a lot of energy

2. The rapid bumping of small pieces by the molecules in a liquid or a gas is called Brownian Movement.

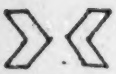
3. Particles move more rapidly if they are given more HEAT ENERGY. They may then be able to bump together and react chemically.

4. A molecule is the smallest part of a compound which can exist in a free and separate state.

5. Bumping of gas molecules against the walls of a container gives rise to pressure.

6. Pressure increases in a smaller space, that is, pressure increases if the volume is decreased.

7. Pressure decreases if there are fewer molecules in the space.



8. Pressure increases if the energy of the molecules increases, that is, if the gas is heated without being allowed to expand.

9. A pressure gauge is used to measure pressure.